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February 19, 2021

VIA ELECTRONIC FILING

The Honorable Jocelyn G. Boyd
Chief Clerk/Executive Director
Public Service Commission of South Carolina
101 Executive Center Drive, Suite 100
Columbia, SC 29210

Re: Petition of Duke Energy Carolinas, LLC and Duke Energy Progress, LLC for Approval of CPRE Queue Number Proposal, Limited Waiver of Generator Interconnection Procedures, and Request for Expedited Review
Docket No. 2018-202-E

Dear Ms. Boyd:

Pursuant to the Public Service Commission of South Carolina's ("Commission") Order No. 2019-247 issued on April 9, 2019, in the above-captioned docket, Duke Energy Carolinas, LLC and Duke Energy Progress, LLC (collectively, the "Companies") hereby respectfully provide the Commission an update on the Companies' most recent Distributed Energy Resources ("DER") Technical Standards Review Group ("TSRG") meeting held on January 20, 2021.

The following attachments enclosed with this update provide a more detailed account of the previous TSRG meeting and issues discussed:

- **Attachment A:** January 20, 2021 Meeting Agenda
- **Attachment B:** January 20, 2021 Minutes and Attendance
- **Attachment C:** Inverter Volt-Var Study Update
- **Attachment D:** Update and Discussion-Action Plan to Implement 1547-2018
- **Attachment E:** DER Commissioning Update
- **Attachment F:** Implementation of IEEE 1547-2018 Guidelines (Redline)
- **Attachment G:** Implementation of IEEE 1547-2018 Guidelines (Clean)

As described in the Companies' June 6, 2019 Report in this docket, the TSRG webpage, https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg, provides meeting materials from each prior TSRG meeting, as well as other technical standards documents. The next TSRG meeting is tentatively scheduled for April 28, 2021.

Sincerely,

Rebecca J. Dulin

Attachments

C: Parties of Record (via email w/ attachments)

Attachment A

Interconnection Technical Standards Review Group (TSRG)
Duke Energy Carolinas/Progress
Meeting Agenda
January 20, 2021

In-person meeting converted to web meeting to follow distancing guidelines for COVID-19

9:00	Meeting Administrator remarks
9:02	Safety & Welcome – Wes Davis, Duke
9:05	IEEE 1547 implementation plan – Anthony Williams, Duke
9:30	Periodic self-inspection plan update – Kevin Chen, Duke
10:30	Break
10:45	Second Volt-VAR study scope – Anthony Williams, Duke
11:30	TSRG meeting participants – Anthony/Wes, Duke
11:40	NCCEBA/SC SBA merger – John Gajda, Strata Solar
11:55	Wrap up & next meeting date – Wes Davis, Duke (Recommend April 21)
12:00	ADJOURN

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

January 20, 2021

I. Opening

This is a regular meeting called to order at 9:00 AM. Consistent with COVID restrictions, the meeting was conducted by web conference.

Meeting facilitator: Anthony Williams

Minutes: Anthony Williams

II. Record of Attendance

Member Attendance

Name	Affiliation	Attendance
Kevin Chen	Duke Energy	present
Wes Davis	Duke Energy	present
Jonathan DeMay	Duke Energy	present
Huimin Li	Duke Energy	present
Orvane Piper	Duke Energy	present
Bill Quaintance	Duke Energy	present
Scott Reynolds	Duke Energy	absent
Anthony Williams	Duke Energy	present
Stephen Barkaszi	Duke Energy	present
Ben Brigman	Ecoplexus	present
Paul Brucke	Brucke Engineering	present
David Brueck	Southern Current	absent
Matt Delafield	R-E Services	present
Jason Epstein	Southern Current	absent
Adam Foodman	O2 Energies EMC	present
Bruce Fowler	BAM Energy	present
Sean Grier	Duke Energy	absent
Scott Griffith	Duke Energy	absent
John Gajda	Strata Solar	present
Chuck Ladd	Ecoplexus	present
Bruce Magruder	BAM Energy	absent
Brad Micallef	Solar Operations Solutions	present
Luke O'Dea	Cypress	absent
Luke Rogers	Birdseye Renewable Energy	absent
Chris Sandifer	SCSBA	present
Mike Whitson	PowerOn Energy	present
John Wilson	Southern Current	present
James Wolf	Yes Solar Solutions	absent
Jay Lucas	NC Public Staff	absent

Name	Affiliation	Attendance
James McLawhorn	NC Public Staff	absent
Dustin Metz	NC Public Staff	present
Tommy Williamson	NC Public Staff	present
Dawn Hipp	SC Office of Regulatory Staff	absent
Sarah Johnson	SC Office of Regulatory Staff	absent
Robert Lawyer	SC Office of Regulatory Staff	absent
Morgan O'Neil	SC Office of Regulatory Staff	present

Guest Attendance

Name	Affiliation	Attendance
Wei Ren	EPRI for Duke Energy	present
Devin Van Zandt	EPRI for Duke Energy	present
Kelsy Green	Advanced Energy for Duke Energy	present
Ken Jennings	Duke Energy	present

III. Current agenda items and discussion

1) The agenda was emailed prior to the meeting.
2) Wes provided the welcome and safety message

3) PRESENTATION: IEEE 1547 implementation plan – Anthony Williams, Duke
   A) Presentation will be provided with the meeting minutes
   B) Discussion – There was discussion to clarify the difference between the enter service delay and enter service ramp period. The former is the delay after a site is energized and the latter is the ramp rate for bringing the DER up from 0% to 100% power.
   C) Industry question – When is enter service applicable?
      (i) Duke response – The ramp limit is understood to be 0-100% active power for 300 sec, which is the same rate as 10% over 30sec. This limit is expected to be used during the morning start up but also and mainly applicable to mid-day starts or returns to service when the active power would have the capability to make an abrupt output change.
   D) Industry question – How will the Guidelines be applied to existing sites?
      (i) Duke response – 1547-2018 implementation is not retroactive. Existing sites were connected under the Standard at the time.
      (ii) <u>ACTION ITEM – The Guidelines will be reviewed and this point clarified.</u>
   E) Industry question – Will or how will these be referenced in the IA?
      (i) Duke response – All options concerning this are on the table; it has not been decided. Initial thoughts are that the Guidelines would be included in the IA by reference and version number. It would also be good to attach the applicable version to the IA too, but as a separate document. But Duke does not plan to include the detail of the guidelines in the IA itself. That would be a duplication of information. Maintaining the

requirements as a separate document is expected to make it easier to understand and also easier to maintain the content over time.

F) Industry question – Is 0.9 pf rating, which is actually closer to 43.6%, as good as 44% in the Standard?
   (i) Duke response – Yes, a power factor rating of 0.9 meets the intent of the 44% requirement although it is actually a little lower.
   (ii) <u>ACTION ITEM – Duke will note in the Guidelines that meeting either the 44% or a 0.9 pf rating both satisfy the Guidelines.</u>

4) PRESENTATION: Periodic self-inspection plan update – Kevin Chen, Duke
   A) Presentation will be provided with the meeting minutes
   B) Discussion – There was feedback that it was very good to have the schedule laid out for the year end commissioning and it helped to coordinate and motivate Duke and developer teams to complete more tests than last year.
   C) Industry question – Can anyone attend training?
      (i) Duke response – Yes, the training is open to everyone without limitation. The volunteers in the self-inspection pilot program are required to attend the training. It will be recorded and shared with TSRG members.
   D) Industry question – What were the main reasons for projects that wanted to complete commissioning by the end of the year not meeting their goal? Could the completion rate be improved?
      (i) Duke response – The key challenge was the overall delayed schedule due to COVID impact. Duke usually collects a list of planned projects from developers in August. For any project with uncertainties, the developer would typically make a clear decision no later than mid-October. However, in 2020, there were uncertain projects until the final list was created in November.

      Duke anticipates the same challenge in 2021. Earlier scheduling/planning and more communication would help improve the commissioning process. Duke will keep improving the commissioning process to meet customer's need.

      There were more projects under the conditional commissioning process when the inspection happened after 10/1/2020. 2020 was the 4th year Duke implemented the conditional commissioning process and the conditional PTO letter to help developers meet their financial goals. For projects that received the conditional PTO letter, Duke considers them as connected in 2020.

5) PRESENTATION: Second Volt-VAR study update – Anthony Williams, Duke
   A) Presentation will be provided with the meeting minutes
   B) Discussion – It was noted that adding the DEP Yukon control to the model was a good improvement. No changes to the information format or methodology was recommended.

6) TSRG meeting participants – Anthony/Wes, Duke
   A) Discussion – Duke noted that in addition to members a new observer category of TSRG participant was created. Members participate in the meetings discussions and observers are stakeholders that only listen to the meeting. Overall CCEBA indicated that the new meeting structure was acceptable.

7) NCCEBA/SC SBA merger – Foodman
   A) Discussion – CCEBA is the new organization that combined the subject organizations. CCEBA is the Carolinas Clean Energy Business Association and Foodman is the chair. Gajda is the chair of their interconnection committee.

8) Wrap up & next meeting date – Wes Davis, Duke
   A) Discussion – Duke asks that more DER consider volunteering for the pilot self-inspection program; the goal is 5 sites.
   B) Next meeting planned to be a web conference.
      (i) After emails following the meeting, April 28 was the final date selected. (April 21, 2021 was discussed during the meeting and tentatively set).

IV. Closing

This meeting concluded at 11:07 PM

V. Attachments

1) Agenda, "TSRG Agenda 2021_0120, Rev 0.pdf"
2) Presentations
   A) IEEE 1547 implementation plan, "TSRG Implement 1547 Update, Jan 20 2021, Rev 0.pdf"
   B) Periodic self-inspection plan update, "DER commissioning_TSRG_01202021.pdf"
   C) Second Volt-VAR study update, "Volt-VAR study update, 2021-01-20, Rev0.pdf"
3) References
   A) 1547 Guidelines with edits, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 2C"
   B) 1547 Guidelines latest version, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 3"

TSRG: Inverter Volt-VAR Study Update

Anthony C Williams, DER Technical Standards

January 20, 2021

DUKE ENERGY

Second Study Overview

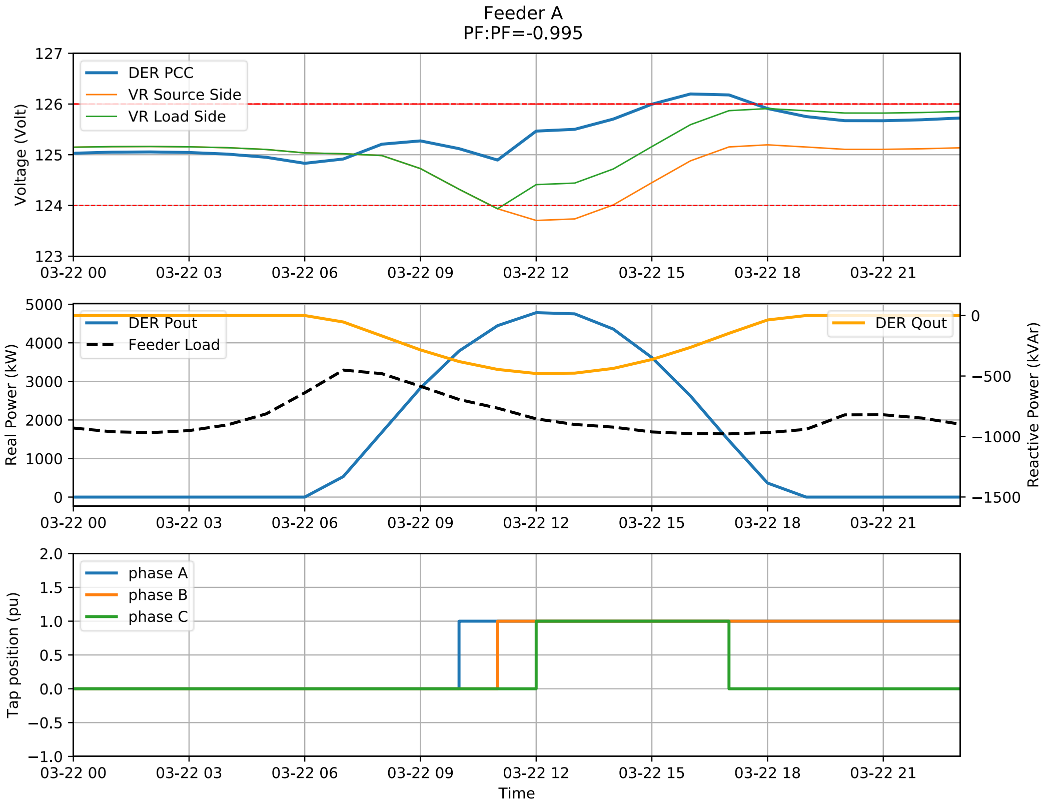
- More emphasis on higher voltage feeders so that less DER forces the overvoltage
- Calculate P and Q responses
- Consider a broader variety of controller types
  - Limited controller setting variations: approximately 6 volt-var, 8 pf, 5 watt-var
  - Continued use of volt-watt to backup the primary controller
- Expand the attributes monitored during the study; to inform conclusions
- Quasi-Static Time Series (QSTS) simulation using 8760 hourly load and solar profile
- Compare monitored attributes across the feeders for the various controller types
  - Inform policy development to guide application of DER voltage and reactive power controls, and
  - Develop methods to a) provide a quick assessment of reactive power control effectiveness at a potential UDER interconnection point, and b) indicate the most appropriate type of control
- Final report February, presentation at the following TSRG

Recent Methodology Improvements

- Yukon capacitor control logic modeled for DEP
  - Provides more reasonable statistics of substation Q demand
- Long term dynamic simulation methods
  - Time dependency (sequencing) of each time step being modeled
  - Next state dependent on last state, not initial state
- Interaction and setting coordination between reactive power controlled DER on the same feeder
- Impact of voltage regulator (upstream to DERs) included in optimal control development

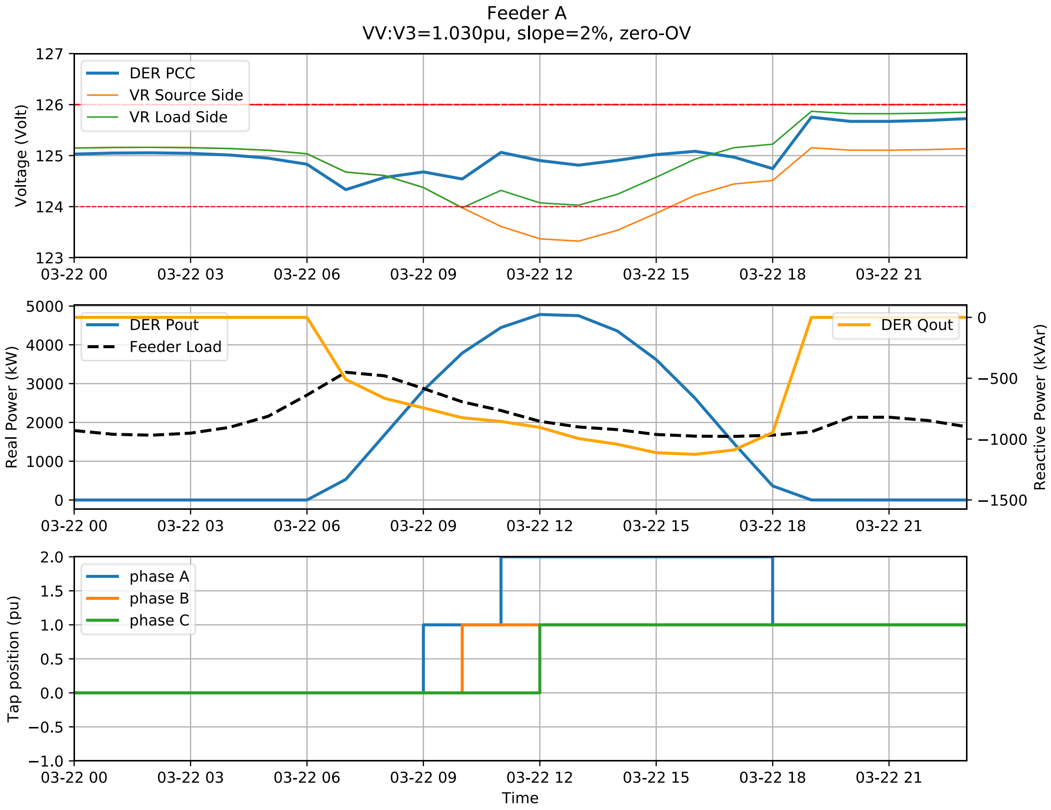
VR + DER Case with Violation

- Station regulator interaction with DER reactive power injection
- DER without VR tap changes resolves the overvoltage
- If conditions cause the voltage at the VR to be near the lower bandwidth
- Reactive injection causes VR to raise taps
- Typically causes violation because voltage limit harder to maintain



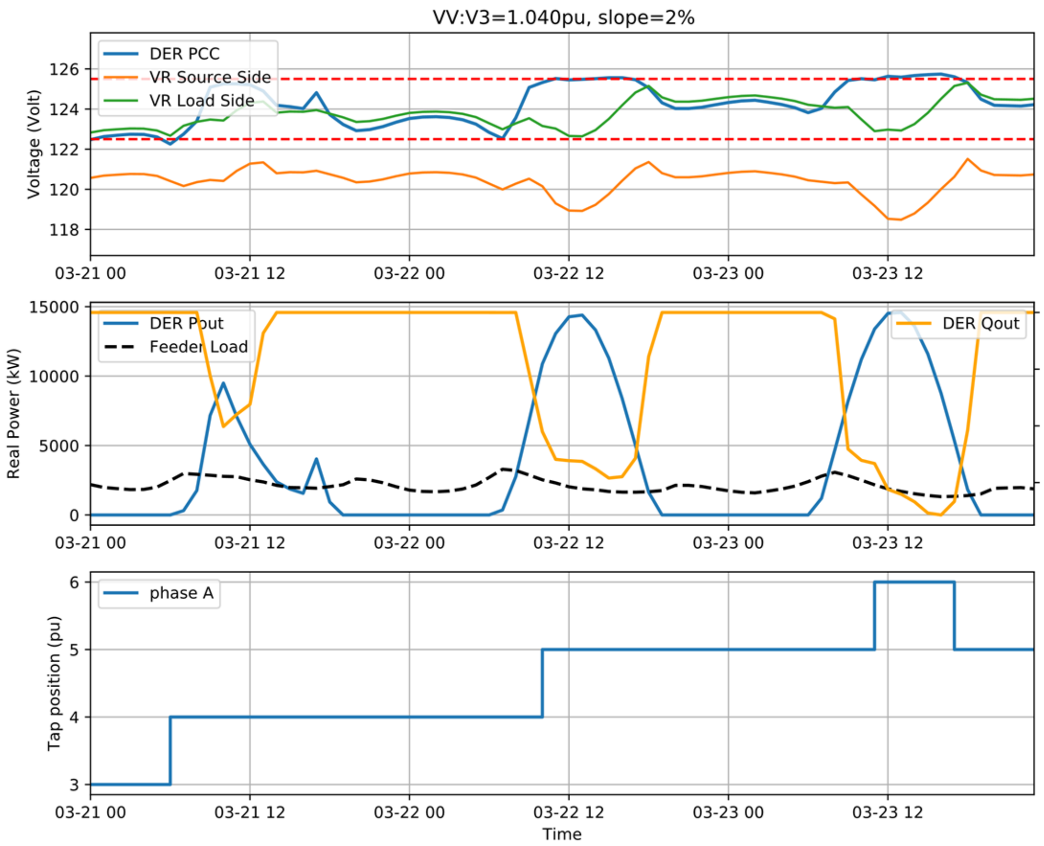
VR + DER Case without Violation

- Same issue, different outcome
- Reactive injection still causes VR to raise taps
- There is enough margin to voltage limit in this case to absorb the rise
- This unacceptable operation is less observable in the field
- The DER and VR are working against each other; creating unnecessary reactive power flow



Coordinated VR + DER Case

- Refined Objective:
  Use DER reactive power to maintain voltage below limit with no VR tap increases
- Use a 3-day response to initialize the tap position and evaluate interaction
- Unknown if balanced solutions can be found for each location



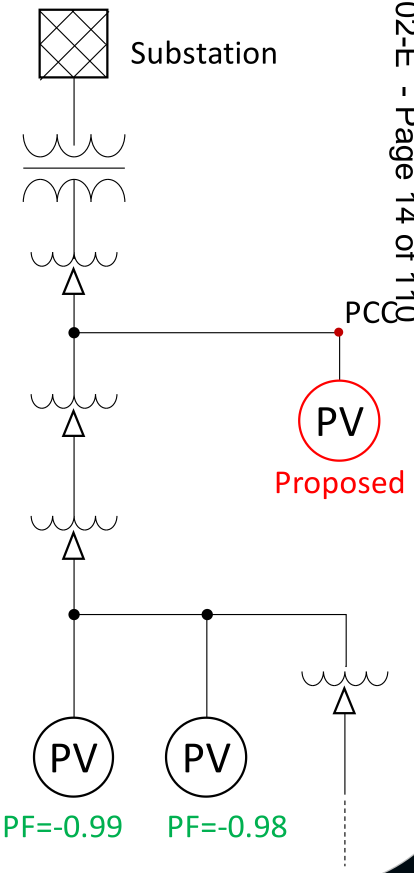
Overview of the Feeder Under Study

Attachment C

Feeder B Characterization Table

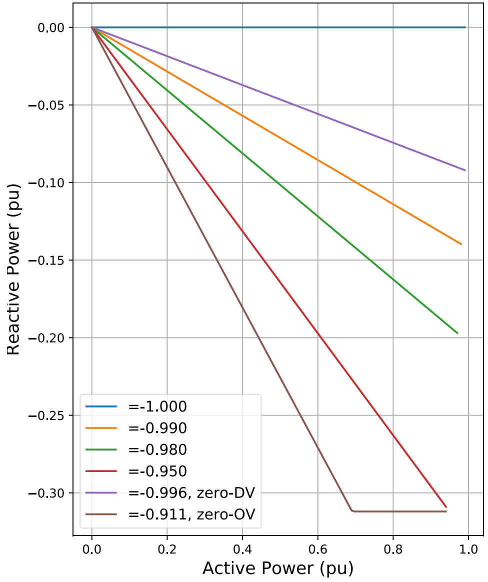
Parameter	Value
Feeder peak load	2.51 MW (PF = 0.966)
Connected DERs	Two existing PV (5.5MW each) One proposed PV (5.0MW, 5.25MVA)
Short Circuit Capacity	231 MVA @ Sub (secondary), 153MVA @ PCC
Z_REG (pu @ 1MVA)	0.0002 + j0.0043
Z_PCC (pu @ 1MVA)	0.0008 + j0.0065
Z_PCC2REG (pu @ 1MVA)	0.0006 + j0.0022 (= Z_PCC - Z_REG)
∆V_Full (pu)	0.0033
∂V / ∂P (puV / MVAr)	0.00066 (= ∆V_Full / Rated_P)
∂V / ∂Q (puV / MVAr)	0.0071
Regulator Control Setting	Vref = 124V, BW = 2V
∆V_Other_PCC2REG_Max (pu)	0.0139

- Values in this table are used to determine the settings for the reactive power controls

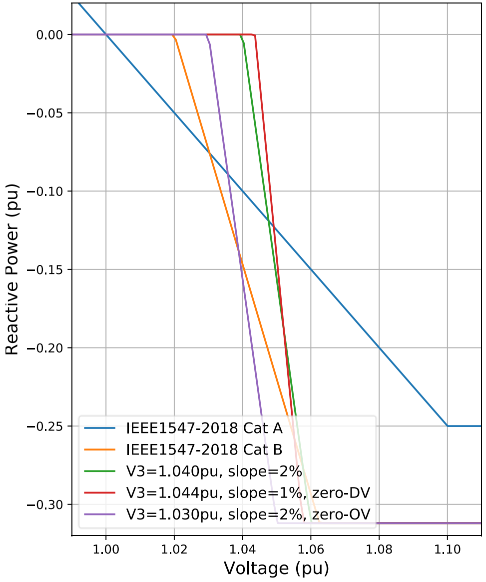


Evaluated Control Options

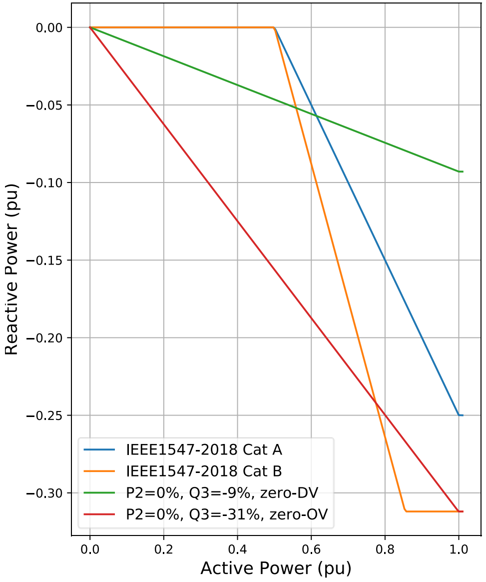
Constant PF



Volt-Var



Watt-Var

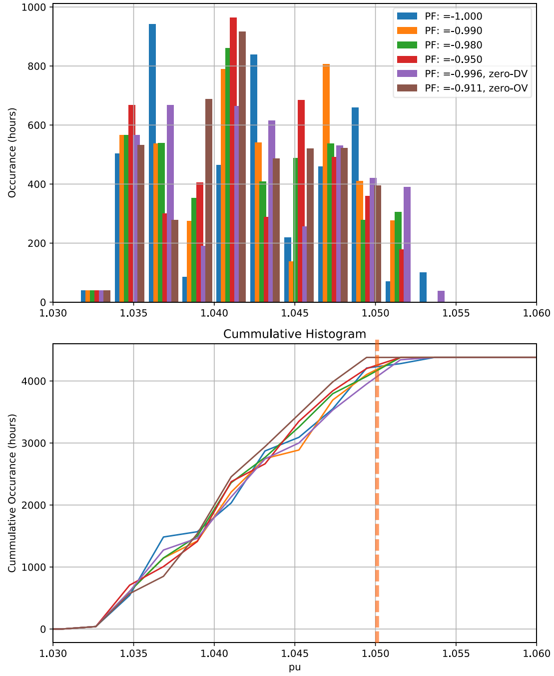


- zero-OV options are more aggressive than zero-DV options to correct the voltage rise from existing DERs

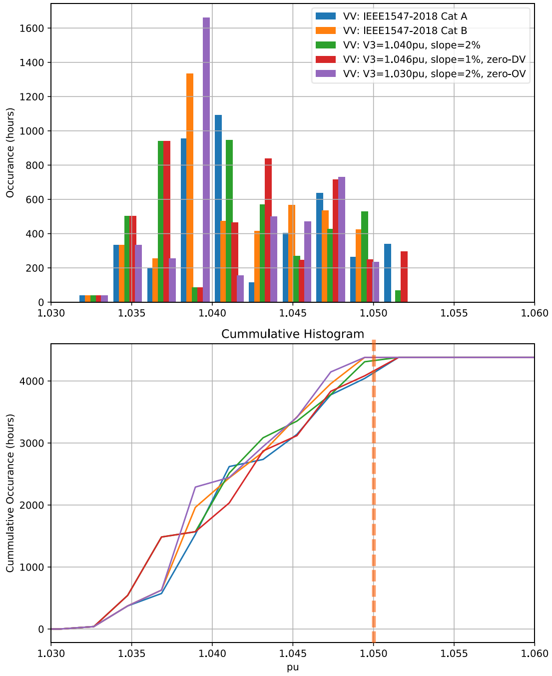
Histogram of PCC Voltage in One Year

Attachment C

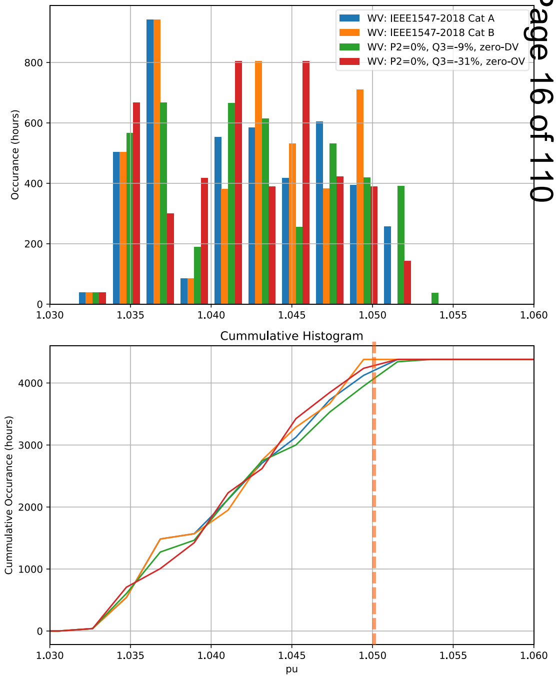
Constant PF



Volt-Var



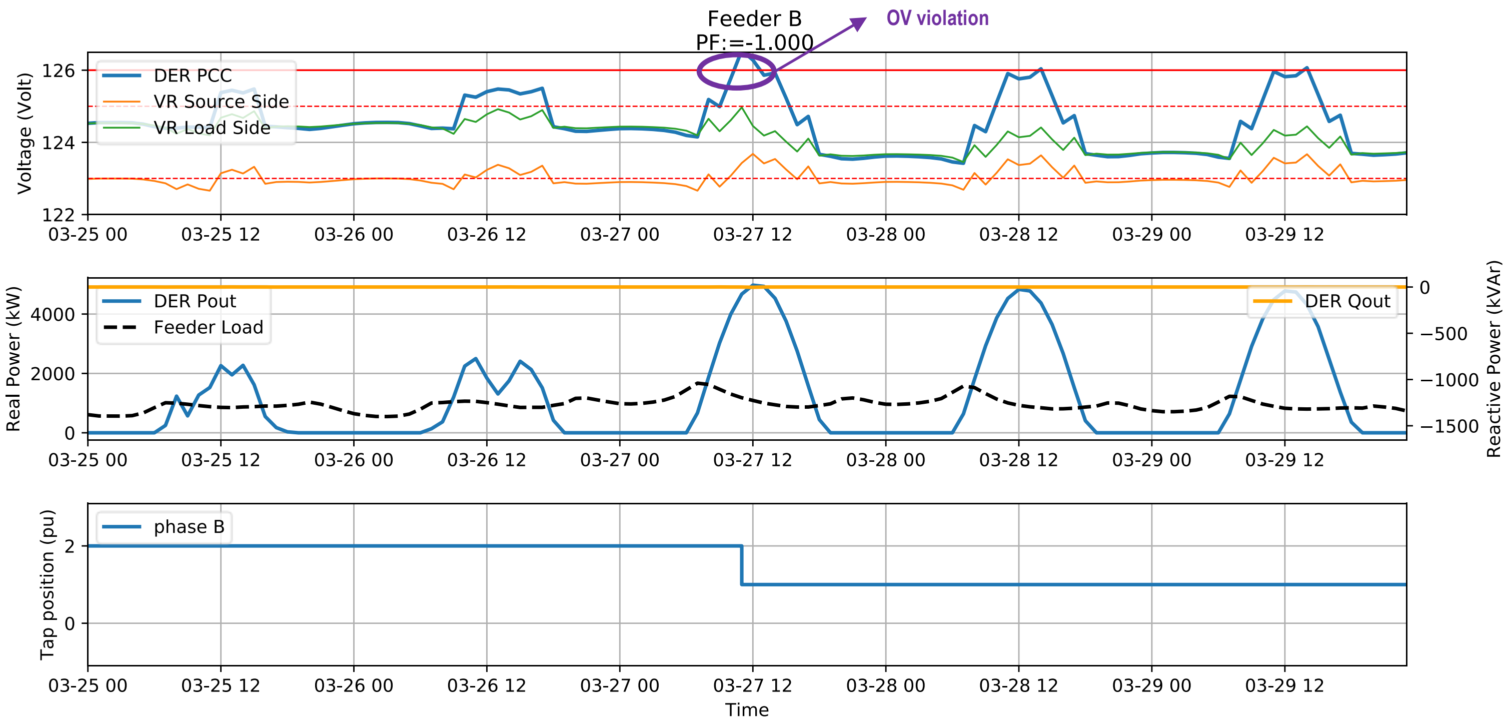
Watt-Var



- All control options are clustered due to proximity of PCC to the voltage regulator
- Zero-OV options work well as they considers the impact of voltage regulator

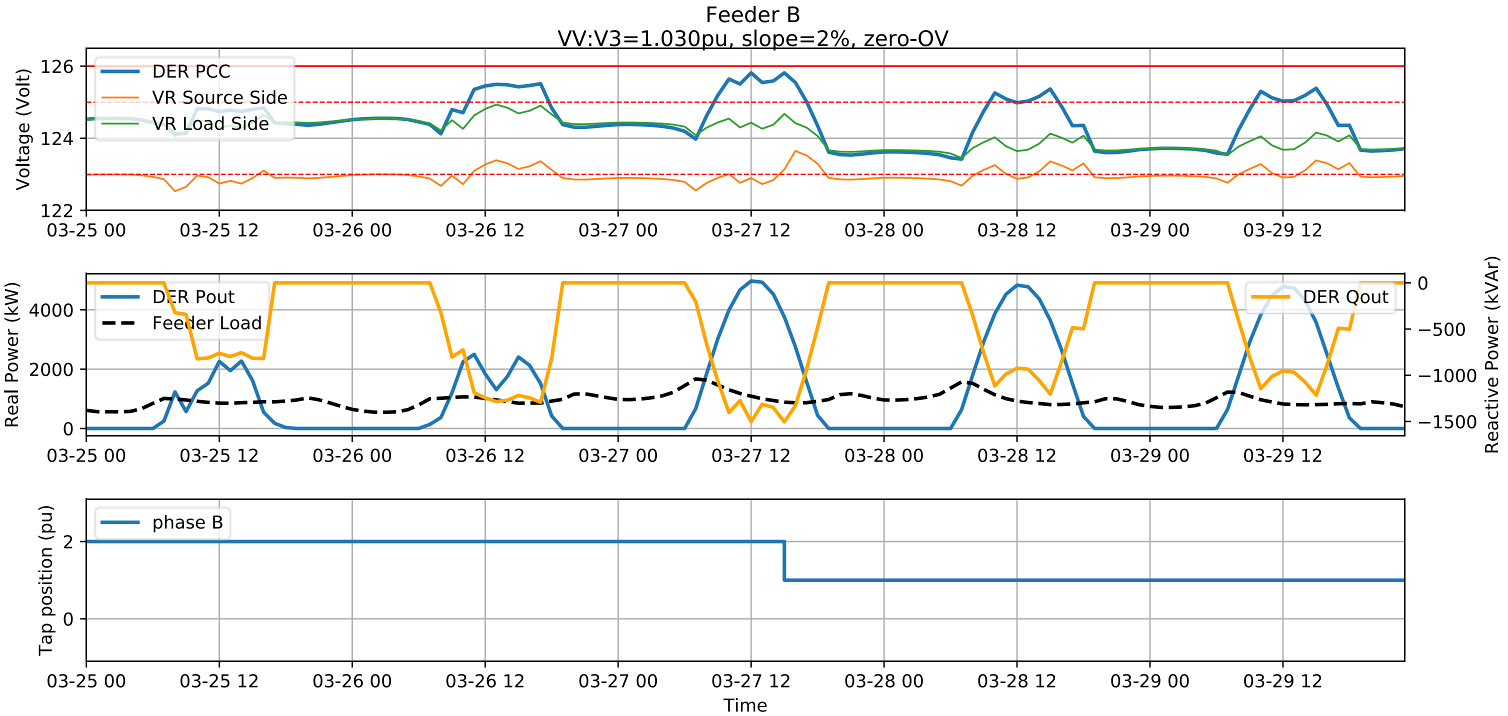
Long Term Dynamic Simulation (Unity PF Mode)

Attachment C



- Five-day (two cloudy and three sunny days) time series simulation
- With unity power factor, DER PCC voltage gets higher than the 105% threshold (i.e., 126V)

Long Term Dynamic Simulation (Volt-Var Mode)



- With the selected Volt-Var control, PCC voltage is always lower than the 105% threshold
- Additional over-voltage margin is required to cover the worst case when VR terminal voltage reaches the top of the BW, 125V, for excursions within the 60 minute time step, and for unanalyzed worse operating conditions

Detailed Summary Tables of All Evaluated Control Options

	PF =-1.000	PF =-0.990	PF =-0.980	PF =-0.950	PF =-0.996, zero-DV	PF =-0.911, zero-OV	VV IEEE1547-2018 Cat A	VV IEEE1547-2018 Cat B	VV V3=1.040pu, slope=2%	VV V3=1.046pu, slope=1%, zero-DV	VV V3=1.030pu, slope=2%, zero-OV	WV IEEE1547-2018 Cat A	WV IEEE1547-2018 Cat B	WV P2=0%, Q3=-9%, zero-DV	WV P2=0%, Q3=-31%, zero-OV
Max V_PCC (pu)	1.055	1.052	1.053	1.051	1.054	1.051	1.052	1.051	1.051	1.052	1.051	1.053	1.05	1.054	1.051
hours_(Vpcc>1.05)	264	363	356	253	507	103	379	148	208	446	0	591	45	507	179
min_Vpcc	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033
hours_(Vpcc<0.95)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
hours_(Volt-Watt ON)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
max_Vinv	1.06	1.05	1.049	1.043	1.054	1.04	1.05	1.044	1.047	1.051	1.039	1.05	1.048	1.054	1.043
hours_(Vinv>1.05)	1295	86	0	0	532	0	0	0	0	304	0	116	0	532	0
min_Vinv	1.033	1.033	1.033	1.032	1.033	1.03	1.032	1.03	1.033	1.033	1.031	1.033	1.029	1.033	1.033
hours_(Vinv<0.95)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
max_Vfdr	1.061	1.062	1.062	1.062	1.061	1.061	1.062	1.061	1.062	1.061	1.061	1.062	1.061	1.061	1.062
hours_(Vfdr>1.05)	2514	2645	2759	2869	2547	2861	3122	3503	2614	2514	3510	2514	2514	2547	2802
min_Vfdr	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033
hours_(Vfdr<0.95)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
max_sub_kW	2513	2513	2513	2513	2513	2513	2513	2513	2513	2513	2513	2513	2513	2513	2513
min_sub_kW	-14847	-14831	-14795	-14698	-14847	-14698	-14837	-14793	-14826	-14841	-14687	-14755	-14605	-14847	-14687
max_sub_MVAr	1	1	2	2	1	2	1	2	1	1	2	2	2	1	2
min_sub_MVAr	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
max_sub_Amps	357	358	357	356	358	356	358	357	358	358	356	357	355	358	356
max_fdr_loading (%)	57	57	57	56	57	56	57	57	57	57	56	57	56	57	56
hours_(fdr_loading>100%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DER MWh	9114	9112	9108	9096	9114	9096	9113	9109	9112	9114	9096	9103	9084	9114	9094
DER MVArh	1	-1298	-1849	-2979	-846	-3744	-2068	-3200	-1045	-435	-3822	-1096	-1889	-847	-2844
total_INV_MWh	9138	9137	9133	9122	9138	9123	9138	9135	9137	9138	9124	9128	9110	9138	9121
total_INV_MVArh	304	-989	-1534	-2645	-542	-3394	-1753	-2869	-736	-131	-3477	-786	-1562	-542	-2513
Max Increased_INV_Loss kW *	0	1	1	3	0	4	1	2	1	1	4	2	5	0	3
Increased_INV_Loss MWh	0	1	2	5	0	8	2	5	1	0	7	1	4	0	4
Max Tradeoff kW	6	20	55	157	4	157	14	67	25	11	167	97	250	4	167
Tradeoff MWh	1	2	7	19	1	19	2	6	2	1	18	12	30	1	20
max_fdr_loss_kW	457	458	459	454	457	454	458	459	458	457	454	457	454	457	454
Feeder Loss MWh	502	506	508	512	504	515	511	517	505	502	519	504	506	504	512
max_fdr_loss_kVAr	2869	2877	2881	2861	2871	2861	2875	2882	2878	2874	2861	2878	2859	2871	2861
Feeder Loss MVArh	3161	3173	3181	3208	3166	3230	3186	3210	3173	3163	3226	3171	3193	3166	3204

* Assuming 1% conduction loss for DER inverter

- This table is used to compare and select the optimal control options

Simplified Table to Focus on those Optimal Options

	PF =-1.000	PF =-0.996, zero-DV	PF =-0.911, zero-OV	VV V3=1.040pu, slope=2%	VV V3=1.046pu, slope=1%, zero-DV	VV V3=1.030pu, slope=2%, zero-OV	WV P2=0%, Q3=-9%, zero-DV	WV P2=0%, Q3=-31%, zero-OV
Max V_PCC (pu)	1.055	1.054	1.051	1.051	1.052	1.051 ⬇	1.054	1.051
hours_(Vpcc>1.05)	264	507	103	208	446	0 ⬇	507	179
DER MWh	9114	9114	9096	9112	9114	9096 ⬇	9114	9094
DER MVArh	1	-846	-3744	-1045	-435	-3822 ⬆	-847	-2844
Max Increased_INV_Loss kW	0	0	4	1	1	4 ⬆	0	3
Increased_INV_Loss MWh	0	0	8	1	0	7 ⬆	0	4
Max Tradeoff kW	6	4	157	25	11	167 ⬆	4	167
Tradeoff MWh	1	1	19	2	1	18 ⬆	1	20
Feeder Loss MWh	502	504	515	505	502	519 ⬆	504	512
Feeder Loss MVArh	3161	3166	3230	3173	3163	3226 ⬆	3166	3204

- Although different control options result in different levels of DER reactive power absorption (i.e., “DER MVArh”), the impact to DER energy yield (i.e., “Tradeoff MWh”) and feeder losses (i.e., “Feeder Loss MWh” and “Feeder Loss MVArh”) is limited

Attachment C

DUKE ENERGY®

*BUILDING A **SMARTER** ENERGY FUTURE*℠

Metrics

- Site specific (fixed)
  - Rated Pgen, Qgen at PCC and inverter
  - SCC at Station, PCC
  - X, from PCC back to source
  - R, from PCC back to source
  - PCC Voltage, Basecase (P=Q=0)
  - PCC Voltage, Initial (P=Prated, Q=0)
  - Min load kva/Peak load kva
  - Feeder head power flow, kW and kVAR
  - ΔV/ΔP (Presp, derivative of voltage variation to real power injection)
  - ΔV/ΔQ (Qresp, derivative of voltage variation to reactive power injection)
  - Qresp/Presp = (dV/dQ) / (dV/dP)
  - ΔV/ΔPrated (total voltage change at rated active power)
  - ΔV/ΔQrated (total voltage change at rated reactive power)
- Controller specific
  - Overvoltage Magnitude, PCC, Feeder, Inverter (V)
  - Overvoltage Occurrences, PCC, Feeder, Inverter
  - Feeder Active Power Max, Min (kW)
  - Feeder Reactive Power, Max, Min (kVAR)
  - Total MWh, MVARh, at PCC, Inverter
  - Tradeoff MW, MWh

Attachment D

Update and Discussion: Action Plan to Implement 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

DER Technical Standards
January 20, 2021

DUKE ENERGY

Agenda

- Review main revisions
  - Current version is “Duke Energy IEEE 1547 Implementation Guidelines, Rev 3”
    - Rev 2C is the redline version of Rev 3
- Discussion

Priority Groups 1 – 5 Review

1st	• Reactive power and voltage control • Power quality
2nd	• Voltage tripping and ride through • Frequency tripping and ride through
3rd	• Most important sections of Section 4, General Tech Specs
4th	• Most commonly applied sections of Section 4, General Tech Specs
5th	• Remaining sections of Section 4, General Tech Specs

Priority Table Updates, Group 1

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B 35° C ambient or higher at rated voltage	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test

Priority Table Updates, Group 2

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test

Priority Group 1 Revisions

- Significant changes to Section 5.2 – Reactive power capability of the DER
- Divided 7.4 into two sections
  - Added new topic, Section 7.4.1 – Limitation of overvoltage over one fundamental frequency period
- Editorial change to move text from Section 7.4 to the proper section, 7.3

Priority Groups 2, 3, 4 Revisions

- Further clarification and timer settings for Section 4.10 – Enter service

The DER shall not enter service or ramp faster than the times stated below. A randomized time delay is optional and not currently used within the Duke system. As noted in the standard, DER increasing active power steps greater than 20% of Nameplate Active Power rating shall require approval during the system interconnection study process.~~following time delays shall be used~~:

Time Delay	Parameter Label	RDER setting (seconds)	UDER setting (seconds)
Enter Service Delay	ES_DELAY	300	300
Enter Service Ramp Period	ES_RAMP_RATE	300	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off

While the active power is ramping during the enter service period, the reactive power shall follow the configured mode and settings.

When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is dependent on the Configuration Active Power Rating per the table below:~~rate of change duration is based on 120 MW/minute, which is 2 MW/second.~~

Rate of Change Duration	Parameter Label		RDER setting (seconds)	UDER setting (seconds)
ESS ≤ 1 MW	None		~~5~~2	n/a
ESS > 1 MW ~~and ≤ 10 MW~~	None		n/a	ESS MW rating / (2 MW/sec)~~5~~
~~ESS > 10 MW~~			~~-~~	~~10~~

Priority Group >5 Updates

- DUK-27 Section 4.7 – Prioritization Of DER Responses
  - Finalized test requirements (use UL certification)
- Updated the Verification and test requirements in several of these sections

Recently Completed Sections

- DUK-05 Section 7.3 – Limitation Of Current Distortion
- DUK-27 Section 4.7 – Prioritization Of DER Responses

Previously Completed Sections

- DUK-13 Section 4.5 – Cease to energize performance requirement
- DUK-28 Section 4.8 – Isolation device
- DUK-23 Section 4.9 – Inadvertent energization of the Area EPS
- DUK-29 Section 4.11.1 – Protection from electromagnetic interference
- DUK-30 Section 4.11.2 – Surge withstand performance
- DUK-22 Section 4.11.3 – Paralleling device
- DUK-26 Section 4.12 – Integration with Area EPS grounding, ready to be implemented
- DUK-01 Section 5.2 – Reactive power capability of the DER
- DUK-05 Section 7.2.3 – Flicker
- ~~DUK-04 Section 7.4 – Limitation of overvoltage contribution~~ (should have been 7.3)

Feedback

- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide both comments and also propose a specific change:

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
example Recommendation format	10	3	The types of faults is too limited. Include single line to ground faults.	Include SLG faults

  - Suggesting the exact change to the Guidelines reinforces the main point of the comment and provides more information that Duke can specifically address
- Comments will be taken during the meeting and the form will be distributed after the meeting
- Stakeholders may provide written feedback using the feedback form by emailing to: DER-TechnicalStandards@duke-energy.com

Attachment E

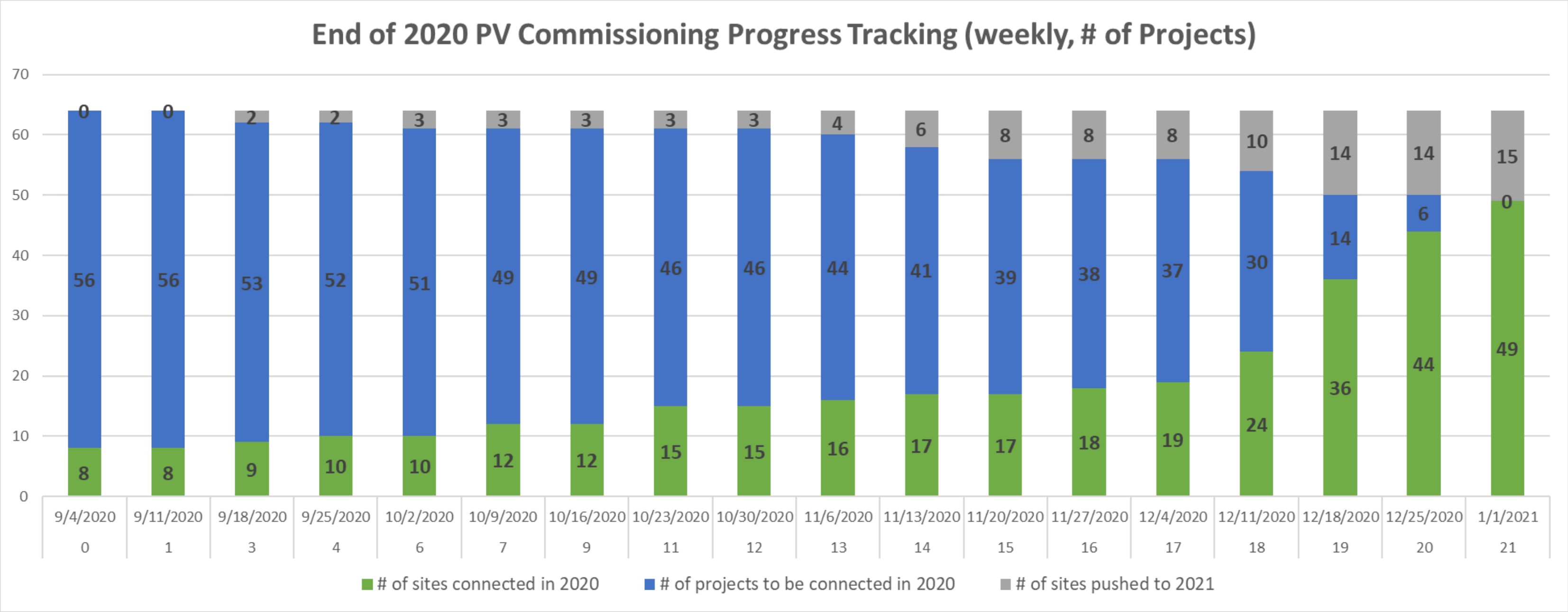
DER Commissioning Update

Kevin Chen 1/20/2020

DUKE ENERGY

- 2020 Solar Commissioning Summary
- Self-inspection Update
- Q&A, open discussion

2020 Solar Commissioning Summary



Year	Total Connected	Between Q1 - Q3	In Q4	Full process	Conditional PTO
2020	49	10 (47.6%)	39 (139%)	21 (67.7%)	28 (156%)
2019	49	21	28	31	18

Challenges

- New developer, new contractor
- New technology, new device
- Weather
- COVID impact
  - An overall delayed schedule
  - Supply chain constraints and resources limit
- Peak workload before deadline
- Decisions made under pressure
- Significant increase in DEC (2020 - 21 total, 18 after Sept; 2019 - 11 total, 4 after Sept)
- High volume projects with conditional PTO letter

Actions Taken and Accomplishment

- Started planning for end of 2020 commissioning in May.
- All developers received the updated commissioning process documents by mid-September.
- Started weekly tracking of a full list expected projects from 9/1.
- The technical training was pre-recorded and uploaded.
- The end-of-year conditional commissioning process started from 10/1.
- In the week of 10/12 – 10/16, we put every project on calendar for its inspection.
- In the week of 12/7 – 12/11, we put every project on calendar for its commissioning test.
- Maximized flexibility in approving for conditional PTO letter.

Forecast 2021

- We anticipate no major change in the workload and challenges in 2021.
- The process will continue to update and improve from the lessons learned.

- 4th Quarter Solar Commissioning Update
- Self-inspection Update
- Q&A, open discussion

Documents shared with TSRG:

1. Process document clean version in PDF (December 2020)
2. Instruction manual clean version in PDF (December 2020)
3. Report template clean version in WORD (July 2020)
4. Report template (device info and settings) in EXCEL (July 2020)
5. Self-Inspection Sample Report in PDF (April 2020)

Additional material:

- Full list of issues from pilot periodic inspection in 2018 and 2019
  - It will be served as reference in the technical training.

- **Self-inspection for previously uninspected generating facilities** – This program is designed to address risks at previously uninspected facilities.
- **Uninspected Facilities** – Generating Facilities that were interconnected prior to the point in time at which Duke implemented an inspection program.
- Three companies volunteered to participate the pilot program.
- We currently plan to have training on self-inspection in first half of February.
- Duke expects to collect self-inspection report from volunteer sites in the second half of March, and provide update at next TSRG meeting in April.
- Further refine the process with lessons learned from the pilot, through TSRG.
- Start the self-inspection for previously uninspected facilities in 2021.

- The training is to go over the findings from AE's pilot inspection in 2018 and 2019 at 9 previously uninspected sites.
  - **Immediate safety issues** – These are the construction quality problems that violate industry codes and standards, and are imminently likely to endanger life or property or damage either the utility's system or customer's generating facilities.
  - **Potential reliability or power quality issues** – These are the construction quality problems that may develop over time into something with the potential to either cause disruption or deterioration of service to other customers.
- The target attendees for the training should be the engineering resources at your choice that are going to perform self-inspection for you.
- The training will be online live presentation, and recorded for playback.
- Non-technical discussion is left out of the training and to be covered in separate meetings as necessary.

- 4th Quarter Solar Commissioning Update
- Self-inspection Process Update
- Q&A, open discussion

DUKE ENERGY®

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 2C

January 20, 2021

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Revision	Date	Description
0	3/31/2020	Initial issue
1	7/21/2020	General update prior to July 2020 TSRG meeting
2	10/28/2020	General update prior to Oct. 2020 TSRG meeting
2C	1/20/2021	General update prior to Jan. 2021 TSRG meeting

CONTENTS

INTRODUCTION

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

CONSIDERATION OF IEEE 1547 SECTIONS THAT COULD INCREASE INTERCONNECTION CAPABILITY

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

i) 4.6.2 Capability to limit active power
ii) 5.3 Voltage and reactive power control
iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

CONSIDERATION OF IEEE 1547 SECTIONS THAT IMPACT GRID SUPPORT

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

PRIORITY OF IMPLEMENTING THE IEEE 1547 TECHNICAL SPECIFICATIONS AND REQUIREMENTS

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

1

2 **Duke Energy Selected Order of Precedence for IEEE 1547 Sections**

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B 35° C ambient or higher at rated voltage	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	TBD, Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	TBD, Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	TBD, Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	TBD, Yes	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	TBD, Yes	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-103)	8.1	Unintentional islanding	TBD	Yes	-
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

1

LOGISTICS OF IMPLEMENTING OF IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the implementation will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification. Prior to requiring IEEE 1547-2018, Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA may mutually agree to implement those available functions as needed.

PLANT REQUIREMENTS

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

Voltage and Reactive Power Category B

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 4.2 – REFERENCE POINTS OF APPLICABILITY (RPA)

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling), which is also known as the point of delivery or change of ownership point on the medium voltage side of the DER transformer(s). The ~~and the~~ RPA for net meter installations is the PoC (point of connection) at the inverter terminals ~~is the RPA for net meter installations~~.

Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:

a) Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*

b) Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]

Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]

For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

The final position must consider the variety of RDER and UDER interconnections and identify the RPA for each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. Zero sequence continuity is not a factor for UDER, so the ~~The~~ RPA for UDER is the PCC (point of common coupling at the utility interconnection point). ~~and the PoC (point of connection) is the~~The RPA for ~~the~~ net meter installations must consider a variety of conditions, as noted in the decision trees, H.1 and H.2. Note that Section 4.12 also addresses grounding and zero sequence continuity.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will to review DER design documents to confirm the location of the RPA is correct. ~~To be determined.~~

~~Duke plans to review DER design documents to verify the DER meets this requirement.~~

Implementation of this section requires publishing the final technical position ~~and integrating verification requirements into the overall commissioning test program~~.

SECTION 4.3 – APPLICABLE VOLTAGES

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the section is implemented as written. The expected outcome is that

RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at the EPS voltage level and used for inverter functions.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: To be determined.

The applicable voltage should be identified in the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 4.5 – CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service setting to "disabled" as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

This section is ready to be implemented.

SECTION 4.6 – CONTROL CAPABILITY REQUIREMENTS

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

Duke accepts the capabilities in the following sections as written:

- 4.6.1 Capability to disable permit service
- 4.6.2 Capability to limit active power
- 4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication interface.

For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting at the local EPS.

Application to RDER has not been assessed.

Note that 4.6.2 is essentially part of the system impact study (SIS) process now because the maximum active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other variables.

Duke does not plan to implement real-time control during the initial implementation of the Standard. Significant technical studies are required to address concerns and consider remote real-time control of the active power limit. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Interoperability requirements: The present automation controller implementation uses an Analog Output sent via SCADA to control active power.

Verification and test requirements: Duke will review UL certification tests, type tests, design documents, and equipment specifications to identify the capability of the DER to meet this performance requirement. Duke's current policy requires a utility owned interconnection recloser for UDER >= 1MW. In this case the permit service is implemented by controlling the utility owned recloser. For DER >= 250kW and <1MW, Duke allows the option of installing the small DG interface instead of the utility owned recloser. In this case, the permit service is implemented at the DER unit through the small DG interface.~~To be determined~~.

~~Duke plans to review type tests, design documents, and equipment specification to identify the capability of the DER to meet this performance requirement. Duke will evaluate if the existing inspection and commissioning test process is sufficient to verify performance and the applicable test requirements of IEEE 1547.1 will be considered.~~

Implementation of this section requires publishing the final technical position.~~Implementation of this section requires integrating verification requirements into the overall commissioning test program.~~

SECTION 4.7 – PRIORITIZATION OF DER RESPONSES

Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review UL certification testing, type tests results, and design documents to evaluate if a DER can meet this requirement.

~~Duke plans to finalize the scope of inspection and commissioning process to this requirement, following review and incorporation of the commissioning tests requirements in IEEE 1547.1-2020 and UL 1741 SB.~~

~~Implementation of this section requires integrating verification requirements into the overall commissioning test program.~~

This section is ready to be implemented. ~~Implementation of this section includes establishing the verification requirements.~~

SECTION 4.8 – ISOLATION DEVICE

Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

This section is ready to be implemented.

SECTION 4.9 – INADVERTENT ENERGIZATION OF THE AREA EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

SECTION 4.10 – ENTER SERVICE

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.10.2 Enter service criteria
4.10.3 Performance during entering service
4.10.4 Synchronization

Duke must still determine the enter service criteria and enter service time delays. Note that while the Standard mentions Range B of ANSI C84.1, that voltage is at the service level (low side of the service transformer) and not at the primary side. Therefore, the settings in the Standard would be more relevant to RDER than UDER that has the RPA and PCC at the primary side of the DER transformer. The RDER values are common in the industry and are Standard defaults.

When entering service, the DER shall not energize the Area EPS until the following conditions are met~~following criteria will be developed for 4.10.2 and 4.10.3~~:

Enter service value	Parameter Label	RDER setting (Service tx sec)	UDER setting (DER tx pri)
Minimum Voltage	ES_V_LOW	≥ 0.917 p.u.	≥ p.u.
Maximum Voltage	ES_V_HIGH	≤ 1.05 p.u.	≤ p.u.
Minimum Frequency	ES_F_LOW	≥ 59.5 p.u.	≥ p.u.
Maximum Frequency	ES_F_HIGH	≤ 60.1 p.u.	≤ p.u.

Note: The parameter labels are based on the public EPRI technical update document number 3002020201, "*Common File Format for Distributed Energy Resources Settings Exchange and Storage*."

The final UDER settings are still under evaluation. Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The DER shall not enter service or ramp faster than the times stated below. A randomized time delay is optional and not currently used within the Duke system. As noted in the standard, DER increasing active power steps greater than 20% of Nameplate Active Power rating shall require approval during the system interconnection study process.~~following time delays shall be used~~:

Time Delay	Parameter Label	RDER setting (seconds)	UDER setting (seconds)
Enter Service Delay	ES_DELAY	300	300
Enter Service Ramp Period	ES_RAMP_RATE	300	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off

While the active power is ramping during the enter service period, the reactive power shall follow the configured mode and settings.

When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is dependent on the Configuration Active Power Rating per the table below:~~rate of change duration is based on 120 MW/minute, which is 2 MW/second.~~

Rate of Change Duration	**Parameter Label**		**RDER setting (seconds)**	**UDER setting (seconds)**
ESS ≤ 1 MW	None		~~5~~2	n/a
ESS > 1 MW ~~and ≤ 10 MW~~	None		n/a	ESS MW rating / (2 MW/sec)~~5~~
~~ESS > 10 MW~~			~~-~~	~~10~~

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Interoperability requirements: To be determined.

Duke will evaluate if there is value in monitoring the enter service settings.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement. For 4.10.4, Duke plans to review UL certification tests, type tests, and design documents to evaluate DER's synchronization capability meeting this requirement. The on-off test during commissioning will field verify DER's synchronization capability.

~~For 4.10.4, Duke plans to review type tests results and design document to evaluate DER's synchronization capability meeting this requirement. Duke also plans to expand the scope of inspection and commissioning process to test DER for this requirement, following the commissioning tests requirements in IEEE 1547.1.~~

Implementation of this section requires publishing the final technical position and applying the interoperability functionality in the local interface.

SECTION 4.11 – INTERCONNECT INTEGRITY

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.11.1 Protection from electromagnetic interference
4.11.2 Surge withstand performance
4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

SECTION 4.12 – INTEGRATION WITH AREA EPS GROUNDING

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below. Therefore, configurations that are not listed are not approved. It is possible for an IC to submit another winding configuration, however the technical review will significantly delay evaluation of the IR.

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection	
			Inverter	Rotating
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented.

SECTION 5.2 – REACTIVE POWER CAPABILITY OF THE DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is most readily available and can be recorded in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. ~~This is a leading and lagging power factor of 0.90 and~~As a good practice, Duke recommends that all facilities be designed to operate at these pf ratings should the situation arise over the life of the facility that the facility would want this capability ~~is consistent with the lagging pf requirement for Duke the same as transmission generators~~.

Commented [WAC1]: The note here was that this is consistent with the lagging pf requirements for Duke transmission generators and was not directed towards all generators on all systems.

Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The reactive capability ~~information~~ shall be provided on an inverter capability curve (P-Q graph) and shall be based at the~~on~~ rated voltage of the device (1 pu) and an ambient temperature of 35° C. The DER may choose to submit reactive capability data on a higher ambient temperature basis, however that data will still be applied as the 35° C capability (Duke cannot temperature adjust manufacturer data).~~or higher and at the rated voltage of the device.~~

Because operating points on the chart can be difficult to accurately determine, it is recommended that the DER provide ~~Provide any specific~~ the numerical data that defines critical points on the ~~chart~~capability curve. Those points include the Nameplate and Configuration apparent, active, and reactive power ~~parameters as noted in the Standard~~ratings at the leading, lagging, and unity power factors.

Some facilities have operational, design, or other limitations that prevent utilization of the full reactive capability of the device(s). If that is the case, the DER shall specify any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions). If no limitations are submitted, then Duke will consider that the facility has no reactive capability limitations. Duke recommends submittal of a facility capability curve that includes any limitations.

~~These details for supplemental devices are tentative and there are details and clarifications that Duke still needs to address.~~

Supplemental Devices

If the DER includes supplemental devices, capability data must be provided for each device at rated voltage of the device and an ambient temperature of 35° C. Subject to the same conditions above, the DER may elect to submit data at a ~~or~~ higher ambient temperature~~and at the rated voltage~~. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a brief written description and an acceptable power flow model of the device. If the supplemental device is ~~are~~ static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified. Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

~~For large scale DER that provide the utility to DER transformer, the composite capability curve shall be provided on the secondary side. In that case, the DER must supply all the Duke required transformer modeling information. For net metered interconnections, the composite capability curve shall be provided on the voltage base of the service transformer secondary.~~

~~Additionally, along with the individual and composite capability curves, the DER must include any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions).~~

Again, any limitations that prevent the full reactive capability of the device(s) to be utilized shall be specified and Duke recommends submittal of a facility capability curve that includes the limitations.

[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

~~At this time, Duke does not have the capability to remotely control or manage distribution connected reactive power resources centrally. However, there is some expectation that functionality may be necessary within the life of the DER, so there are interoperability requirements for both autonomous operation as well as remote control and adjustment of setpoints. The interoperability requirements for remote control are expected to include those for autonomous operation.~~

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for DER to prove its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

The Standard lists several forms of reactive power control:

- Constant power factor mode
- Constant reactive power mode
- Voltage-reactive power mode
- Active power-reactive power mode

Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings. Because the impact of UDER reactive injection can be large, Duke limits the reactive capability that can be used for reactive power control to 0.95 power factor.

In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed. Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration for residential-scale inverters as well. The reactive control method and settings should consider existing operational requirements as well as mitigation of the high voltages that can occur with the addition of DER. No change can be made on one part of the system that does not affect another part. Therefore, the study will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts, remediation of impacts, and controlling the impact on the transmission system. Distribution Providers must comply with agreements and requirements of the transmission entities. As such, an evaluation of transmission impacts is important.

Significant technical studies are required to evaluate these functions and analyze the consequences. The studies began at the end of 2019 and will continue in 2021~~0~~. This will continue to be an agenda item for the TSRG meetings will focus on the most useful control modes and settings that are applied locally in the inverter and are autonomous.

Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision. ~~Duke is developing the objectives for the second volt-var study.~~

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the VAR priority mode and reactive power mode to Duke, and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation. For example, some DER require a 0-100% setpoint while others require an actual value in kVAR. In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While priority can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints for each mode.

At this time, Duke does not have the capability to remotely control or manage distribution connected reactive power resources. However, there is some expectation that functionality may be necessary or available within the life of the DER. Facilities may want to make provision for interoperability capabilities that include both autonomous operation as well as remote control and adjustment of setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 5.4 – VOLTAGE AND ACTIVE POWER CONTROL

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 6.2 – AREA EPS FAULTS AND OPEN PHASE CONDITIONS

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: To be determined.

Duke Energy must evaluate if there are any interoperability requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

SECTION 6.3 – AREA EPS RECLOSING COORDINATION

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

SECTION 6.4.1 – MANDATORY VOLTAGE TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.4.2 – VOLTAGE DISTURBANCE RIDE-THROUGH REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

See Section 1.4 for the abnormal performance category.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

SECTION 6.5.1 – MANDATORY FREQUENCY TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.5.2 – FREQUENCY DISTURBANCE RIDE-THROUGH REQUIREMENTS

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)

UL certification testing should verify the inverter will ride through a 3 Hz/s excursion. That being the case, no generator on the utility system shall intentionally trip for ROCOF using protective relaying or DER controller functions. DER tripping for ROCOF, if available, should be off or disabled. The DER shall certify that protective relay settings & controller settings do not intentionally trip for ROCOF.

> This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.6 Voltage phase angle changes ride-through

> This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.7 Frequency-droop (frequency-power) capability

> This function is still under evaluation. Per Standard table 22, a specification of the droop, deadband, and associated parameters is required for Category III~~may be needed~~.

6.5.2.8 Inertial response

> Duke Energy has not determined the guidelines for this subsection. This capability is not required by the Standard but is permitted.

Interoperability requirements: To be determined.

> It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 7.2.2 – RAPID VOLTAGE CHANGES

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is consistent with the Standard and does not plan further evaluation.

Interoperability requirements: To be determined.

Based on the type of inrush mitigation used, there could be some status points that are useful for situational awareness. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements.

Verification and test requirements: The installation evaluation is currently included in the scope of Duke's interconnection inspection process, but the performance of the mitigation is not currently tested. A power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-energize test). Duke will develop a test procedure and criteria to evaluate the performance of a RVC mitigation solution as part of the commissioning tests.

Implementation of this section requires applying the interoperability functionality in the local interface and integrating verification requirements into the overall commissioning test program.

SECTION 7.2.3 – FLICKER

Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

This section is ready to be implemented.

SECTION 7.3 – LIMITATION OF CURRENT DISTORTION

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

Interoperability requirements: No specific requirements for this section. Installation of a power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.1 – LIMITATION OF OVERVOLTAGE OVER ONE FUNDAMENTAL FREQUENCY PERIOD

Duke Energy adopts these requirements as written in the Standard.

Part of 7.4.1 is based on the inverter design and operation and part is based on the specific design of the interconnection and the Area EPS itself. The ability of the inverter to detect and limit overvoltage will be verified by UL certification testing. However, the DER facility must still be analyzed during system impact study to verify the impact of the combined inverter and Area EPS is below the limits of the Standard. The limits defined in parts a) and b) must be verified by power system study.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results, and examine design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position.

SECTION 7.4.2 – LIMITATION OF CUMULATIVE INSTANTANEOUS OVERVOLTAGE

~~Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.~~

Duke Energy has not determined the guidelines for this section. More industry experience or analysis could be essential to address this issue. Duke does not plan to implement this section until IEEE 1547.1 is revised and UL 1741 certification tests include this verification. At that time, Duke expects to adopt these requirements as written in the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position.

SECTION 10.3, 10.4 – NAMEPLATE AND CONFIGURATION INFORMATION

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
    - The rating is the most capacity the system is designed to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.
    - Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.
- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

UNADDRESSED REQUIREMENTS OF IEEE 1547-2018

The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the completion of the higher priority topics. Concerning the clauses and sections not addressed in this document, Duke Energy expects that the DER shall conform to the Standard itself as written.

APPENDIX – IEEE 1547-2018 BENCHMARKING

Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant Consulting, Inc.

TABLE B.1. BENCHMARKING OF IEEE 1547-2018 FUNCTIONALITIES IMPLEMENTATION

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

1

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 3

January 20, 2021

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Revision	Date	Description
0	3/31/2020	Initial issue
1	7/21/2020	General update prior to July 2020 TSRG meeting
2	10/28/2020	General update prior to Oct. 2020 TSRG meeting
3	1/20/2021	General update prior to Jan. 2021 TSRG meeting

CONTENTS

INTRODUCTION

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

CONSIDERATION OF IEEE 1547 SECTIONS THAT COULD INCREASE INTERCONNECTION CAPABILITY

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

i) 4.6.2 Capability to limit active power
ii) 5.3 Voltage and reactive power control
iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

CONSIDERATION OF IEEE 1547 SECTIONS THAT IMPACT GRID SUPPORT

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

PRIORITY OF IMPLEMENTING THE IEEE 1547 TECHNICAL SPECIFICATIONS AND REQUIREMENTS

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B 35° C ambient or higher at rated voltage	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	TBD, Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	TBD, Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	TBD, Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	TBD, Yes	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	TBD, Yes	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-103)	8.1	Unintentional islanding	TBD	Yes	-
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

LOGISTICS OF IMPLEMENTING OF IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the implementation will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification. Prior to requiring IEEE 1547-2018, Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA may mutually agree to implement those available functions as needed.

PLANT REQUIREMENTS

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

Voltage and Reactive Power Category B

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 4.2 – REFERENCE POINTS OF APPLICABILITY (RPA)

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling), which is also known as the point of delivery or change of ownership point on the medium voltage side of the DER transformer(s). The RPA for net meter installations is the PoC (point of connection) at the inverter terminals.

Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:

a) Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*

b) Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]

Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]

For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

The final position must consider the variety of RDER and UDER interconnections and identify the RPA for each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. Zero sequence continuity is not a factor for UDER, so the RPA for UDER is the PCC (point of common coupling at the utility interconnection point). The RPA for net meter installations must consider a variety of conditions, as noted in the decision trees, H.1 and H.2. Note that Section 4.12 also addresses grounding and zero sequence continuity.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will to review DER design documents to confirm the location of the RPA is correct.

Implementation of this section requires publishing the final technical position.

SECTION 4.3 – APPLICABLE VOLTAGES

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the section is implemented as written. The expected outcome is that RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at the EPS voltage level and used for inverter functions.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: To be determined.

The applicable voltage should be identified in the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 4.5 – CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service setting to "disabled" as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

This section is ready to be implemented.

SECTION 4.6 – CONTROL CAPABILITY REQUIREMENTS

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

Duke accepts the capabilities in the following sections as written:

- 4.6.1 Capability to disable permit service
- 4.6.2 Capability to limit active power
- 4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication interface.

For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting at the local EPS.

Application to RDER has not been assessed.

Note that 4.6.2 is essentially part of the system impact study (SIS) process now because the maximum active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other variables.

Duke does not plan to implement real-time control during the initial implementation of the Standard. Significant technical studies are required to address concerns and consider remote real-time control of the active power limit. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Interoperability requirements: The present automation controller implementation uses an Analog Output sent via SCADA to control active power.

Verification and test requirements: Duke will review UL certification tests, type tests, design documents, and equipment specifications to identify the capability of the DER to meet this performance requirement. Duke's current policy requires a utility owned interconnection recloser for UDER >= 1MW. In this case the permit service is implemented by controlling the utility owned recloser. For DER >= 250kW and <1MW, Duke allows the option of installing the small DG interface instead of the utility owned recloser. In this case, the permit service is implemented at the DER unit through the small DG interface.

Implementation of this section requires publishing the final technical position.

SECTION 4.7 – PRIORITIZATION OF DER RESPONSES

Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review UL certification testing, type tests results, and design documents to evaluate if a DER can meet this requirement.

This section is ready to be implemented.

SECTION 4.8 – ISOLATION DEVICE

Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

This section is ready to be implemented.

SECTION 4.9 – INADVERTENT ENERGIZATION OF THE AREA EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

SECTION 4.10 – ENTER SERVICE

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.10.2 Enter service criteria
4.10.3 Performance during entering service
4.10.4 Synchronization

Duke must still determine the enter service criteria and enter service time delays. Note that while the Standard mentions Range B of ANSI C84.1, that voltage is at the service level (low side of the service transformer) and not at the primary side. Therefore, the settings in the Standard would be more relevant to RDER than UDER that has the RPA and PCC at the primary side of the DER transformer. The RDER values are common in the industry and are Standard defaults.

When entering service, the DER shall not energize the Area EPS until the following conditions are met:

Enter service value	Parameter Label	RDER setting (Service tx sec)	UDER setting (DER tx pri)
Minimum Voltage	ES_V_LOW	≥ 0.917 p.u.	≥ p.u.
Maximum Voltage	ES_V_HIGH	≤ 1.05 p.u.	≤ p.u.
Minimum Frequency	ES_F_LOW	≥ 59.5 p.u.	≥ p.u.
Maximum Frequency	ES_F_HIGH	≤ 60.1 p.u.	≤ p.u.

Note: The parameter labels are based on the publicly available EPRI technical update document number 3002020201, "*Common File Format for Distributed Energy Resources Settings Exchange and Storage.*"

The final UDER settings are still under evaluation. Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The DER shall not enter service or ramp faster than the times stated below. A randomized time delay is optional and not currently used within the Duke system. As noted in the standard, DER increasing active power steps greater than 20% of Nameplate Active Power rating shall require approval during the system interconnection study process.

Time Delay	**Parameter Label**	**RDER setting (seconds)**	**UDER setting (seconds)**
Enter Service Delay	ES_DELAY	300	300
Enter Service Ramp Period	ES_RAMP_RATE	300	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off

While the active power is ramping during the enter service period, the reactive power shall follow the configured mode and settings.

When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is dependent on the Configuration Active Power Rating per the table below:

Rate of Change Duration	**Parameter Label**		**RDER setting (seconds)**	**UDER setting (seconds)**
ESS ≤ 1 MW	None		2	n/a
ESS > 1 MW	None		n/a	ESS MW rating / (2 MW/sec)

Interoperability requirements: To be determined.

Duke will evaluate if there is value in monitoring the enter service settings.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement. For 4.10.4, Duke plans to review UL certification tests, type tests, and design documents to evaluate DER's synchronization capability meeting this requirement. The on-off test during commissioning will field verify DER's synchronization capability.

Implementation of this section requires publishing the final technical position and applying the interoperability functionality in the local interface.

SECTION 4.11 – INTERCONNECT INTEGRITY

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.11.1 Protection from electromagnetic interference
4.11.2 Surge withstand performance
4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

SECTION 4.12 – INTEGRATION WITH AREA EPS GROUNDING

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below. Therefore, configurations that are not listed are not approved. It is possible for an IC to submit another winding configuration, however the technical review will significantly delay evaluation of the IR.

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection	
			Inverter	Rotating
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented.

SECTION 5.2 – REACTIVE POWER CAPABILITY OF THE DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is most readily available and can be recorded in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. As a good practice, Duke recommends that all facilities be designed to operate at these pf ratings should the situation arise over the life of the facility that the facility would want this capability.

Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The reactive capability shall be provided on an inverter capability curve (P-Q graph) and shall be based at the rated voltage of the device (1 pu) and an ambient temperature of 35° C. The DER may choose to submit reactive capability data on a higher ambient temperature basis, however that data will still be applied as the 35° C capability (Duke cannot temperature adjust manufacturer data).

Because operating points on the chart can be difficult to accurately determine, it is recommended that the DER provide the numerical data that defines critical points on the capability curve. Those points include the Nameplate and Configuration apparent, active, and reactive power ratings at the leading, lagging, and unity power factors.

Some facilities have operational, design, or other limitations that prevent utilization of the full reactive capability of the device(s). If that is the case, the DER shall specify any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions). If no limitations are submitted, then Duke will consider that the facility has no reactive capability limitations. Duke recommends submittal of a facility capability curve that includes any limitations.

Supplemental Devices

If the DER includes supplemental devices, capability data must be provided for each device at rated voltage of the device and an ambient temperature of 35° C. Subject to the same conditions above, the DER may elect to submit data at a higher ambient temperature. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a brief written description and an acceptable power flow model of the device. If the supplemental device is static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified. Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

Again, any limitations that prevent the full reactive capability of the device(s) to be utilized shall be specified and Duke recommends submittal of a facility capability curve that includes the limitations.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for DER to prove its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

The Standard lists several forms of reactive power control:

- Constant power factor mode
- Constant reactive power mode
- Voltage-reactive power mode
- Active power-reactive power mode

Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings. Because the impact of UDER reactive injection can be large, Duke limits the reactive capability that can be used for reactive power control to 0.95 power factor.

In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed. Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration for residential-scale inverters as well. The reactive control method and settings should consider existing operational requirements as well as mitigation of the high voltages that can occur with the addition of DER. No change can be made on one part of the system that does not affect another part. Therefore, the study will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts, remediation of impacts, and controlling the impact on the transmission system. Distribution Providers must comply with agreements and requirements of the transmission entities. As such, an evaluation of transmission impacts is important.

Significant technical studies are required to evaluate these functions and analyze the consequences. The studies began at the end of 2019 and will continue in 2021. This will continue to be an agenda item for the TSRG meetings will focus on the most useful control modes and settings that are applied locally in the inverter and are autonomous.

Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the VAR priority mode and reactive power mode to Duke, and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation. For example, some DER require a 0-100% setpoint while others require an actual value in kVAR. In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While priority can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints for each mode.

At this time, Duke does not have the capability to remotely control or manage distribution connected reactive power resources. However, there is some expectation that functionality may be necessary or available within the life of the DER. Facilities may want to make provision for interoperability capabilities that include both autonomous operation as well as remote control and adjustment of setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 5.4 – VOLTAGE AND ACTIVE POWER CONTROL

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 6.2 – AREA EPS FAULTS AND OPEN PHASE CONDITIONS

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: To be determined.

Duke Energy must evaluate if there are any interoperability requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

SECTION 6.3 – AREA EPS RECLOSING COORDINATION

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

SECTION 6.4.1 – MANDATORY VOLTAGE TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.4.2 – VOLTAGE DISTURBANCE RIDE-THROUGH REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

See Section 1.4 for the abnormal performance category.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

SECTION 6.5.1 – MANDATORY FREQUENCY TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.5.2 – FREQUENCY DISTURBANCE RIDE-THROUGH REQUIREMENTS

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)
UL certification testing should verify the inverter will ride through a 3 Hz/s excursion. That being the case, no generator on the utility system shall intentionally trip for ROCOF using protective relaying or DER

controller functions. DER tripping for ROCOF, if available, should be off or disabled. The DER shall certify that protective relay settings & controller settings do not intentionally trip for ROCOF.

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.6 Voltage phase angle changes ride-through

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.7 Frequency-droop (frequency-power) capability

This function is still under evaluation. Per Standard table 22, a specification of the droop, deadband, and associated parameters is required for Category III.

6.5.2.8 Inertial response

Duke Energy has not determined the guidelines for this subsection. This capability is not required by the Standard but is permitted.

Interoperability requirements: To be determined.

It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 7.2.2 – RAPID VOLTAGE CHANGES

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is consistent with the Standard and does not plan further evaluation.

Interoperability requirements: To be determined.

Based on the type of inrush mitigation used, there could be some status points that are useful for situational awareness. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements.

Verification and test requirements: The installation evaluation is currently included in the scope of Duke's interconnection inspection process, but the performance of the mitigation is not currently tested. A power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-energize test). Duke will develop a test procedure and criteria to evaluate the performance of a RVC mitigation solution as part of the commissioning tests.

Implementation of this section requires applying the interoperability functionality in the local interface and integrating verification requirements into the overall commissioning test program.

SECTION 7.2.3 – FLICKER

Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

This section is ready to be implemented.

SECTION 7.3 – LIMITATION OF CURRENT DISTORTION

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

Interoperability requirements: No specific requirements for this section. Installation of a power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.1 – LIMITATION OF OVERVOLTAGE OVER ONE FUNDAMENTAL FREQUENCY PERIOD

Duke Energy adopts these requirements as written in the Standard.

Part of 7.4.1 is based on the inverter design and operation and part is based on the specific design of the interconnection and the Area EPS itself. The ability of the inverter to detect and limit overvoltage will be verified by UL certification testing. However, the DER facility must still be analyzed during system impact study to verify the impact of the combined inverter and Area EPS is below the limits of the Standard. The limits defined in parts a) and b) must be verified by power system study.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results, and examine design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.2 – LIMITATION OF CUMULATIVE INSTANTANEOUS OVERVOLTAGE

Duke Energy has not determined the guidelines for this section. More industry experience or analysis could be essential to address this issue. Duke does not plan to implement this section until IEEE 1547.1 is revised and UL 1741 certification tests include this verification. At that time, Duke expects to adopt these requirements as written in the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position.

SECTION 10.3, 10.4 – NAMEPLATE AND CONFIGURATION INFORMATION

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
  - The rating is the <u>most</u> capacity the system is <u>designed</u> to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.
  - Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.
- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

UNADDRESSED REQUIREMENTS OF IEEE 1547-2018

The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the completion of the higher priority topics. Concerning the clauses and sections not addressed in this document, Duke Energy expects that the DER shall conform to the Standard itself as written.

APPENDIX – IEEE 1547-2018 BENCHMARKING

Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant Consulting, Inc.

TABLE B.1. BENCHMARKING OF IEEE 1547-2018 FUNCTIONALITIES IMPLEMENTATION

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			